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MATHEMATICAL TECHNIQUES FOR NONLINEAR SYSTEM THEORY.(U)
1978 R E KALMAN AFOSR-76-3034

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MATHEMATICAL TECHNIQUES FOR NONLINEAR SYSTEM THEORY

INTERIM SCIENTIFIC REPORT

Air Force Grant AFOSR-76-3034
Period ending 31 May 1977

Center for Mathematical System Theory
University of Florida
Gainesville, FL 32611

Principal Investigator: Professor R. E. Kalman

1. WORK COMPLETED

(a) Nonlinear realization theory. A major part of the effort under this grant is concerned with nonlinear realization theory. The first phase of this work has been completed with the dissertation of SONTAG [1978] (actually completed in 1976 and currently in the process of publication). The dissertation has been written in the style of a mini-textbook, in order to provide full background material from the field of algebraic geometry. The principal new results concern a unified treatment on nonlinear systems via formal power series, resulting in a setup that contains many previous results by BROCKETT, SUSSMAN, and FLIESS.

SONTAG also obtained many results concerning the characterization of these systems via Volterra series, input-output difference equations, etc. He has given a very general formulation of the Hankel-matrix realization technique in the nonlinear case, showing that many previous results can be unified in this way. SONTAG's work (to be published as a research monograph) is the mathematical basis for further ongoing research at the Center in nonlinear system theory. Some preliminary results of this work have been published as SONTAG and ROUCHALEAU [1976].

(b) Theory of linear systems over rings. Research in this area, which was a major focus of effort at the Center from 1972 through 1976, is now largely completed. Some further effort will be made in terms of preparing additional publications.

The main results published or submitted are SONTAG [1976a and 1976b], ROUCHALEAU and SONTAG [1978].

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20. ABSTRACT *(Continue on reverse side if necessary and identify by block number)*

New results have been obtained concerning a unified treatment on nonlinear systems via formal power series. Many results have been obtained concerning the characterization of these system via Volterra series, input-output difference equations, etc. A very general formulation of the Hankel-matrix realization technique has been obtained in the nonlinear case, showing that many previous results can be unified in this way. The work on the realization of multilinear response maps is being completed. This class on nonlinear system will be the first for which a comprehensive minimal realization theory can be developed.

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2. WORK IN PROGRESS

(a) Nonlinear realization theory. The work of SONTAG has continued along various directions already outlined in his dissertation, for example, concerning a deeper study of the observability problem for nonlinear systems. Several publications are expected at the end of the summer of 1977.

The Principal Investigator is completing his work on the realization of multilinear response maps. There are strong indications that this class of nonlinear systems will be the first for which a comprehensive minimal realization theory can be developed. Especially important in this connection is the doctoral work of PEARLMAN at Imperial College (London), which provides a highly interesting criterion for the quasi-reachability of nonlinear systems of the type occurring in the realization of bilinear response functions. PEARLMAN's dissertation, which is expected to be finished during the summer of 1977 is perhaps the first explicit system-theoretic result about nonlinear reachability which is wholly algebraic (and therefore global) in nature.

(b) Theory of linear systems over rings. We have started some preliminary planning for a tutorial/research conference on this topic to present the results of the last five years. Such a conference will probably take place under (partial) NASA sponsorship in 1978 or, more likely, in 1979. The main participants would be SONTAG, ROUCHALEAU, KAMEN, and (possibly) the Principal Investigator.

3. PUBLICATIONS

E. D. SONTAG

[1976a] "On linear systems and noncommutative rings", Mathematical System Theory, 9: 327-344.

E. D. SONTAG

[1976b] "Linear systems over commutative rings: a survey", Richerche di Automatica, 7: 1-34.

E. D. SONTAG and Y. ROUCHALEAU

[1976] "On discrete-time polynomial systems", J. of Nonlinear Analysis, 1: 55-64.

4. SUBMITTED FOR PUBLICATION

Y. ROUCHALEAU and E. D. SONTAG

[1978] "On minimal realizations of systems over rings", submitted for publication to *J. Comp. Syst. Sci.*

E. D. SONTAG

[1976] "On split realizations of systems over rings", submitted for publication to Information and Control.

[1978] "On the internal realization of polynomial response maps", Ph. D. dissertation, University of Florida, Sept. 1976 (to appear in Springer Lecture Notes on System Science).

E. D. SONTAG and Y. ROUCHALEAU

[1977] "Sur les anneaux de Fatou forts", C. R. Acad. Sci, Paris, 284 A: 331-333.